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Hibernation of the Corn Ear Worm In Southern Connecticut

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For several consecutive years prior to 1935 the corn ear worm (*Heliothis obsoleta F.*) caused serious injury to corn in southern Connecticut during the growing season, particularly in the fall. Outbreaks had occurred occasionally for many years, but not annually. It was apparent that there had been a definite change in status of the insect in this area.

Previous to 1935 a number of experiments had been performed to determine whether or not the corn ear worm hibernated successfully in southern Connecticut. All the results proved negative, and at that time there was no recorded instance of the insect having overwintered there.

In view of the recent annual occurrence of the pest the question arose whether this was due to annual migration of moths, successful hibernation of pupae under conditions not yet known, or to the arrival of the insect through interstate shipment of its green vegetable hosts, particularly corn, tomatoes, and beans. The study described herein was therefore initiated in the summer of 1935 and continued until the spring of 1938 to determine whether the insect did hibernate successfully in the area.

HIBERNATING HABITS OF THE INSECT

In the Northeastern States the corn ear worm spends the period from September to June in the soil as a pupa. The periods during which pupae go into hibernation in the fall and moths emerge early in the summer cover, in each case, from one to two months.

During the fall, larvae which mature in corn ears burrow into the soil. They dig to depths of from 1 to 8 inches below the surface, and then each larva opens a tunnel extending from the deepest point attained to within about half an inch of the surface. The walls of this tunnel are compacted and possibly lined with silk or cementing material; consequently, unless interfered with by an external agency such as earthworms, roots of plants, or heaving during freezing and thawing, the tunnel remains open until the following summer. The purpose of this tunnel is to enable the moth to escape from the soil. When the tunnel is finished, the larva returns to the deepest point, which is slightly enlarged, and within a few days becomes a pupa. The pupa rests in this position for at least nine months, or until the warmth of early summer stimulates its emergence. Then, as a moth, it crawls up to the top of the burrow, forces its way through the narrow barrier of earth, attains the surface, spreads its wings, feeds on the nectar of flowers, mates, and seeks out corn or other suitable plants on which to deposit its eggs.

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SEASONAL ABUNDANCE OF THE INSECT

The seasonal occurrences of the ear worm in southern Connecticut were similar during the period 1935 to 1937, inclusive.

In 1935 full-grown larvae were found during the last week of July in two fields on elevated ground, one at Woodbridge and one at Mount Carmel. Eggs probably had been laid during the first week of July. Elsewhere the insect was scarce or was not found. Infestation continued at a very low rate until mid-August, when populations began to increase. During the first two weeks of September heavy infestations occurred, usually amounting to 100 percent in ears of late sweet corn.

In 1936 larvae were first found on July 13 as partly grown individuals in a field in Hamden. Infestation was at a rate of 4.7 percent of ears in this field, but the insect was much less abundant elsewhere. Eggs probably had been laid during the first week of July. Infestation until mid-August varied from none to 2 percent, but by that time it began to increase, and by September 15 as many as 50 percent of sweet-corn ears, and as many as 25 percent of ensilage corn ears, were attacked.

In 1937 larvae were first found on June 22 in the same field where the earliest infestation was found the previous year. Fifth-instar larvae were recovered at this time, but the infestation was at a rate of less than 1 percent. Eggs apparently had been deposited about June 10. During July and August the insect was very scarce in most cornfields or was not present at all. It began to appear and increase during the last week of August, and by mid-September from 75 to 100 percent of ears of late sweet corn were attacked.

The insect caused no appreciable injury to corn before mid-August in any of the three years. Until that time its population per field was uniformly low.

Infestation each season apparently began with very few individuals. Throughout July and August large acreages of corn in stages of growth attractive to the insect were available, but the individuals of the first brood were scarce and their rate of reproduction was not high enough to cause noticeable infestation of this large acreage. By the third or fourth week of August, however, ripening of the corn and ensilage cutting began, and from that time on the supply of corn in suitable stages of growth for attack by the ear worm rapidly decreased, resulting in a concentration of the expanding population of the insect in the limited acreage of late corn. It was only at this time, during any of the years observed, that economic damage was caused by ear worms. When the relation between the abundance of the ear worm and the acreage of corn in a condition attractive to it is considered, it is believed that all the infestations found throughout each of the three years of observation can be accounted for as natural increase, during two or more generations, from the few individuals that occurred in June or July in the first brood of a year[1].

[1] This explanation of the seasonal abundance was first developed by F. F. Dicke who has presented supporting data in a manuscript entitled "Seasonal Abundance of the Corn Earworm," to be submitted for publication in the *Journal of Agricultural Research*.

COMPARISON OF THE WINTERS 1935-36, 1936-37 and 1937-38

The three winters during which these experiments were conducted were quite variable in severity. That of 1935-36 might be classed as very severe, that of 1936-37 as very mild, while that of 1937-38 was intermediate. During January, February, and March of 1936, snow covered the ground much of the time, often to depths of a foot or more; but in the two succeeding winters little snow cover occurred, especially during the winter of 1936-37, which was nearly snow-free. Thus, during the course of these experiments, a wide range in winter weather occurred. This is indicated in the data given in Table 1, applicable to New Haven.

Of the several environments in which experiments were placed, the climate of Milford was similar to that of New Haven. That of Mount Carmel, at an elevation of 200 feet, and that of Windsor, 45 miles north, were more severe, with minimum temperatures sometimes falling from 10 to 15 degrees lower than at New Haven. The climate of West Dennis, Mass., on the other hand, was somewhat milder than that in New Haven.

METHODS OF STUDY

To study the survival of pupae and the emergence of moths from hibernation, it was necessary to protect pupae against attack by predators, such as moles and skunks, and to trap the emerging moths. For this purpose cages were used such as had been employed in previous studies elsewhere.

Twenty cages 30 inches wide, 30 inches long, and 10 inches deep were constructed of redwood. Lids two inches deep and covered with wire screening were attached with hinges and hooks. The wood was first painted with linseed oil and later with green paint to ensure durability. During summer, cages were sunk in soil in the field to a depth of about nine inches so that the contained soil would become naturally packed by fall. The soil was also packed by treading.

In September of each year, 100 ear worm larvae were allowed to dig into the soil of each cage. Larvae were collected in September of 1935 and 1937 from sweet corn, and in 1936 from ensilage corn. Because of the cannibalistic habits of this insect it was necessary to handle each larva separately. Individuals as nearly full-grown as possible, mostly in the sixth instar, were collected, isolated in two-ounce tin salve boxes, and given fresh, soft kernels of corn daily. When the larvae were nearly mature, the covers were removed and the boxes containing the worms were inverted over the soil in the cages. Here again food was renewed daily as long as they continued to feed. By this method larvae could finish feeding and burrow into the soil at will, without disturbance, during this critical period of their lives. As soon as 100 had burrowed in a given cage, the tin boxes and food refuse were removed.

Cages were usually set out in series, so that one could be examined in the fall and one in the spring, and at least one was allowed to remain for possible moth emergence. The lids were removed after the soil had frozen, were left off during the winter, and replaced in spring before the ground thawed.

TABLE 1. WEATHER RECORDS FOR THE WINTERS 1935-36 TO 1937-38 AT NEW HAVEN, CONN. (U. S. WEATHER BUREAU RECORDS)

	Season	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Mean temperature (°F.)	1935-36	63	54	47	28	28	24	43	46	60	
	1936-37	65	54	41	36	38	34	34	47	61	
	1937-38	63	52	44	33	29	33	41	50	58	
Maximum temperature (°F.)	1935-36	82	73	68	53	53	48	65	78	90	
	1936-37	88	75	71	58	64	52	57	70	90	
	1937-38	92	73	64	47	55	55	72	84	78	
Minimum temperature (°F.)	1935-36	42	33	22	5	1	1	14	30	40	
	1936-37	41	25	15	11	17	10	18	32	41	
	1937-38	42	31	23	17	−1	8	8	25	40	
Precipitation (inches)	1935-36	3.53	.76	4.70	.96	7.56	3.05	6.43	3.46	1.58	32.03
	1936-37	5.04	5.10	1.09	8.34	6.68	2.22	4.33	4.75	1.98	39.53
	1937-38	2.90	5.80	5.80	2.95	4.23	2.91	2.57	2.98	4.28	34.42

Larvae entered the soil of cages during the second and third weeks of September each year. The number digging on each date is given in Table 2. The weather in 1935 and 1936 was favorable for their development and digging activities and the required number entered the soil within about 10 days. Cool, cloudy, or rainy weather during this period in 1937 was unfavorable for their development, and not only did they enter the soil more slowly but many died. In the three-year period a total of 60 cages, each containing 100 individuals, were studied. In 1936 and 1937, these were augmented by 10 cages, each containing 25 individuals. It was not possible to obtain ear worms in sufficient numbers to stock hibernation cages until the second week of September in any of the three years because, as explained in a previous section, it was not until this time that concentrated populations of the insect occurred.

TABLE 2.

DATES WHEN CORN EAR WORM LARVAE DUG INTO THE SOIL OF HIBERNATION CAGES. New Haven, Milford, Mount Carmel, and Windsor, Conn.

Date September	Number of Larvae that Entered the Soil		
	1935-36	1936-37	1937-38
9	....	....	23
10	....	....	50
11	1	....	84
12	2	57	276
13	58	153	111
14	247	305	117
15	297	292	259
16	429	441	157
17	182	258	278
18	116	71	135
19	118	15	59
20	108	8	121
21	32	....	73
22	10	....	43
23	....	86*	102*
24	....	98*	98*
25	....	16*	14
26	....	....	....
27	110*	....	....
28	90*	....	....
Total	1,800	1,800	2,000

* Cages at West Dennis, Mass.

While the larvae were digging into the soil of cages, it was found necessary to protect them from carnivorous ants, that were attracted to and killed larvae entering the soil or feeding under salve boxes. One species in particular, the cornfield ant, *Lasius niger* var. *americanus* Emery (determined by W. M. Mann), was a nuisance in this respect and killed larvae in the first cages set out at Mount Carmel and Milford in July, 1935. In all subsequent experiments, when larvae were present, they were protected by a narrow barrier of kerosene poured on the earth about the cages. When renewed daily, this barrier prevented ants from approaching the cages.

TABLE 3. LOCATION OF HIBERNATION CAGES FOR THE CORN EAR WORM IN SOUTHERN NEW ENGLAND

Environment	Locality	Designation of cages (by serial number)		
		1935-36	1936-37	1937-38
		LARVAE ENTERED HIBERNATION IN SEPTEMBER		
Outdoors:				
In cultivated loam soil	Mt. Carmel, Conn.	2, 3, 4, 5	2, 3, 4, 5	1, 2, 3, 4
	Milford, Conn.	10, 11, 12, 13	10, 11, 12, 13	9, 10, 11, 12
	New Haven Conn.	17, 18	17, 18	17, 18
In cultivated sand	West Dennis, Mass.	19, 20	19, 20	19, 20
In washed sand	Mt. Carmel, Conn.	6	6	.....
	Milford, Conn.	8	8	.....
In alfalfa field	Mt. Carmel,Conn.	15, 16	.....	.....
In cultivated soil covered with corn shocks	Mt. Carmel, Conn.	7	7	.....
	Milford, Conn.	14	14	.....
Protected from rainfall:				
In soil of open shed	Mt. Carmel, Conn.	.....	15, 16	15, 16
In insectary	New Haven, Conn.	.....	.....	5, 6
In soil of tobacco shed	Windsor, Conn.	.....	.....	7, 8, 13, 14
In soil of cubic-foot cages				
In insectary	New Haven, Conn.	.....	22	21
In hay loft of barn	Mt. Carmel, Conn.	.....	23	26
In horse barn	Mt. Carmel, Conn.	.....	24	24
In open shed	Mt. Carmel, Conn.	.....	.....	25
In 40° F. cold room	New Haven, Conn.	.....	25	.....
In basement of office	New Haven, Conn.	.....	26	22
		LARVAE ENTERED HIBERNATION IN JULY-AUGUST		
Outdoors:				
In cultivated soil	Mt. Carmel, Conn.	1	1	.....
	Milford, Conn.	9	9	.....

ENVIRONMENTAL CONDITION OF CAGES

The purpose of this investigation was to determine whether or not pupae survived the winters under any conditions in this area. It was necessary, therefore, to subject them to as many of the environmental conditions that they would meet in nature as the facilities available permitted. The environments chosen for study were different in geographical location, in elevation, in type of soil, in abundance of soil fauna, and in exposure to precipitation, as well as in other factors.

Cages were placed in nine environments in 1935-36 and 1936-37, and in seven in 1937-38, as listed in Table 3. Series were located at Mount Carmel, Milford, and New Haven, Conn., in cultivated loam soil, and at West Dennis, Mass., in cultivated sand. During the first two years, series were also placed in washed sand at Mount Carmel and Milford, Conn., and during the first year two cages were set in an alfalfa field at Mount Carmel. Other cages in cultivated loam at Mount Carmel and Milford were covered with corn shocks during winter.

Following the negative results of the first year, when it was concluded that winter precipitation was responsible in part for failure of pupae to survive, cages were set in locations which were protected from rainfall, such as in soil of an open shed during the second and third years, and in an open insectary and in a tobacco shed during the third year. Smaller cages containing about a cubic foot of earth, into which larvae were allowed to dig, were placed in sheltered locations where cornstalks were sometimes stored during winter.

BEHAVIOR OF INDIVIDUALS THAT ENTERED THE SOIL DURING JULY AND AUGUST

In order to study the possibility that hibernation may begin as early as midsummer, two cages were used, one at Mount Carmel and one at Milford. One hundred larvae entered the soil of each cage between July 30 and August 3, 1935. From the Mount Carmel cage, 94 moths emerged between August 16 and 20; while from the Milford cage, 70 moths emerged between these dates. No further recovery was obtained in either case.

Again, in 1936, similar cages were used. In the Mount Carmel cage, 55 larvae dug into the soil between August 27 and September 2; while in the Milford cage, 60 larvae entered the soil between August 24 and 28. At this time larvae were very scarce and sufficient numbers were not available to stock each cage with 100 individuals. During the first week of September, 20 moths emerged from the Mount Carmel and 11 from the Milford cage. No further recovery of moths was made.

Assuming that the individuals which did not emerge before winter remained in the soil to hibernate, a possible 6 percent began hibernation in the Mount Carmel cage the first week of August, 1935, and a possible 64 percent the last week of August, 1936. Similarly, a possible 30 percent began hibernation in the Milford cage the first week of August, 1935, and a possible 80 percent the last week of August, 1936.

These experiments indicated that although few ear worms began hibernation the first week of August, they entered hibernation in much larger

numbers by the last week of that month. It is probable that the percentage gradually increases from the first of August onwards. Hibernation of individuals that entered the soil in the middle of September was complete, for in none of the three years did moths emerge from these cages in the fall.

Information was also obtained on the possible hibernation of individuals entering the soil during July. The results from two such cages were rendered inconclusive in 1935, because, when an examination was made the following September, it was found that ants had gained access to them. A cage at Mount Carmel, in which larvae entered the soil July 27 to 30 inclusive, was examined on September 16. No live pupae were recovered. A total of 21 empty pupal skins were found at depths of from 0.9 to 3.7 inches below the surface, or an average depth of 1.6 inches. Of the burrows, 13, or 61.9 percent, were open; 7, or 33.3 percent, were partly open; while 1, or 4.8 percent, was closed. Six earthworms were present in this cage. A cage at Milford, in which larvae had entered the soil July 27 to 30 inclusive, was examined on September 17. No live pupae were recovered. A total of 56 empty pupal skins were found at depths from 0.9 to 4.3 inches below

TABLE 4. RESULTS OF EXAMINATION OF CORN

Environment	Locality	Cage No.	Date examined	Number of pupae recovered			Dead larvae recovered
				Alive	Dead	Total	
	CONNECTICUT		FALL				
Outdoors: in cultivated loam soil	Mt. Carmel	4	Nov. 5-6	85	3	88	8
	Milford	13	Nov. 4-5	77	10	87	5
			SPRING				
	Mt. Carmel	2	July 28	0	50	50	0
	Mt. Carmel	3	July 28	0	64	64	0
	Mt. Carmel	5	Apr. 28	0	81	81	0
	Milford	10	July 29	0	68	68	0
	Milford	11	July 30	0	62	62	0
	Milford	12	Apr. 29	0	76	76	0
	New Haven	17	July 16	0	68	68	0
	New Haven	18	July 17	0	75	75	0
	MASSACHUSETTS						
In cultivated sand	West Dennis	19	May 2	0	101	101	0
	West Dennis	20	June 9	0	93	93	0
	CONNECTICUT						
Covered by corn shock	Mt. Carmel	7	July 27-28	0	53	53	0
	Milford	14	July 30	0	80	80	0
In alfalfa field	Mt. Carmel	15	Aug. 3	0	47	47	0
	Mt. Carmel	16	Aug. 4	0	48	48	0
In washed sand	Mt. Carmel*	6	May 18	0	50	50	0
	Milford*	8	May 18	0	50	50	0

* Half of these cages were examined on the stated dates.

the surface, or an average depth of 1.7 inches. Of the burrows, 25, or 44.6 percent, were open; 21, or 37.5 percent, were partly open; and 10, or 17.9 percent, were closed. This cage contained 29 earthworms.

These results seemed to show that no larvae entering the soil during the last week of July hibernated, and that their emergence burrows were partly obliterated during the summer, principally through the activity of earthworms. Larvae entering the soil for pupation at this time did not dig nearly so deeply as those that went into the soil in September; the depths of the burrows of the latter are given in Table 8.

EFFECT OF SNOW COVERAGE ON PUPAL SURVIVAL

In September, 1935, two cages at New Haven (cages 17 and 18, Table 4) were stocked with pupae in the usual way and set up for study of the effect of snow coverage on survival of pupae. The following winter was the only one having sufficient snowfall to make such an experiment possible. One cage was kept free of snow throughout the winter; the second was kept

Ear Worm Hibernation Cages of 1935-36

Total recovery	Depth of pupae in soil (inches)			Condition of the burrows			No. of earthworms	Pupae encumbered by	
	Deepest	Shallowest	Average	Open	Partly open	Closed		Roots	Earthworms
96	6.4	.9	2.7	87	1	0	3	0	1
92	6.1	1.1	2.7	69	13	5	22	0	18
50	3.8	.9	2.2	1	28	21	0	6	.....
64	4.8	.9	2.4	11	28	25	1	6	.....
81	5.1	1.2	2.7	11	44	26	4	0	.....
68	5.5	1.3	3.3	0	21	47	43	34	.....
62	5.3	.7	2.9	1	36	25	22	32	.....
76	5.3	.8	2.8	4	43	29	31	0	.....
68	4.7	1.2	2.2	3	20	45	1	10	.....
75	4.6	.9	2.5	1	42	32	0	18	.....
101	5.6	1.3	3.7	12	69	20	8	0	.....
93	5.7	1.2	3.6	0	88	5	0	16	.....
53	4.8	1.4	2.5	4	27	22	3	22	.....
80	5.5	.9	2.8	1	51	28	37	68	.....
47	3.2	1.2	2.2	0	9	38	30	15	.....
48	4.7	.9	2.7	0	5	43	21	6	.....
50	5.8	.7	3.7	0	23	27	0	0	0
50	5.9	.9	4.0	0	23	27	0	0	0

covered with snow for as long a period as possible. This cage was covered with about 4 inches of snow between November 23 and 27, and from December 29 to January 2. From January 19 to March 3 it was covered with from 6 to 12 inches continuously, and from March 3 to 5 with 2 inches. No pupae survived in either cage. Although the blanket of snow probably protected the pupae against the lowest temperatures, they were killed by other causes.

RESULTS OF EXAMINATION OF CAGES PLACED OUTDOORS

Certain of the cages were examined in November of each year to determine the percentage of pupae which were entering hibernation alive. Others were examined in April and May to discover the percentage that had survived the winter. Still other cages were examined during the following sum-

TABLE 5. RESULTS OF EXAMINATION OF CORN

Environment	Locality	Cage No.	Date examined	Number of pupae recovered			Dead larvae recovered
				Alive	Dead	Total	
	CONNECTICUT		FALL				
Outdoors in cultivated loam soil	Mt. Carmel	2	Nov. 6	85	9	94	2
	Mt. Carmel	3	Feb. 1	61	17	78	0
	Milford	10	Nov. 5	87	3	90	4
			SPRING				
	Mt. Carmel	4	Apr. 28	0	96	96	0
	Mt. Carmel	5	July 27	0	78	78	0
	Milford	11	Apr. 30	0	97	97	0
	Milford	12	July 30	0	86	86	0
	Milford	13	July 24	0	84	84	0
	New Haven	17	May 2	0	93	93	0
	New Haven	18	Aug. 7	0	93	93	0
	MASSACHUSETTS						
In cultivated sand	West Dennis	19	May 4	41	63	104	0
	West Dennis	20	July 23	6*	70	76	0
	CONNECTICUT						
Covered by corn shock	Mt. Carmel	7	July 26	0	62	62	0
	Milford	14	July 29	0	86	86	0
In washed sand	Mt. Carmel**	6	May 7	0	52	52	0
	Milford**	8	May 7	††6	44	50	0
Protected from rainfall in soil of open shed	Mt. Carmel	15	May 1	36	50	86	8
	Mt. Carmel	16	July 28	‡7	86	93	0

* One live pupa and five emerged moths. ** Half of these cages were examined on stated dates. †† One moth emerged from the undisturbed portion of this cage. ‡Three live pupae and four emerged moths.

mer. The results obtained are summarized in Tables 4, 5, and 6, for the winters 1935-36, 1936-37, and 1937-38, respectively.

The soil of cages was examined by shaving it away carefully in a vertical direction with a trowel. When burrows were open, as they usually were in fall and spring, these could be followed downward until a given pupa was located. The soil of one cage could be examined in about three hours. From the soil of 56 cages, a total of 4,428 pupae were recovered, or 79.1 percent of the expected population. In examining the soil of a cage the following information was tabulated: (1) The condition of the pupae, whether alive or dead; (2) depth of the pupae below the surface of the soil; (3) condition of the burrows, whether open, partly open, or closed; (4) abundance of soil fauna, such as earthworms, and occurrence of roots of plants in the burrows.

EAR WORM HIBERNATION CAGES OF 1936-37

Total recovery	Depth of pupae in soil (inches)			Condition of the burrows			No. of earthworms	Pupae encumbered by	
	Deepest	Shallowest	Average	Open	Partly open	Closed		Roots	Earthworms
96	6.9	1.4	3.7	94	0	0	1	0	.....
78	7.4	1.7	4.6	58	11	9	0	0	.....
94	5.8	1.1	3.0	72	10	8	24	0	15
96	6.5	1.3	3.2	16	42	38	15	0	.....
78	5.7	1.5	3.5	16	46	16	2	69	.....
97	5.4	.8	2.7	5	27	65	41	0	37
86	6.1	1.2	3.1	1	46	39	16	26	3
84	6.9	1.1	3.5	3	68	13	16	50	.....
93	6.2	.8	3.2	39	39	15	1	0	3
93	5.8	1.2	3.2	23	43	27	0	0	.....
104	6.4	1.1	3.8	73	25	6	0	25	.....
76	6.7	1.1	3.4	3	6	67	0	48	.....
62	6.7	2.3	3.9	23	38	1	0	48	.....
86	5.9	1.1	3.2	5	46	35	24	13	.....
52	7.4	1.4	3.7	0	0	52	†8	0	.....
50	8.1	1.1	4.7	0	17	33	0	0	.....
94	5.1	.6	2.9	86	0	0	0	0	0
93	5.6	1.1	2.8	93	0	0	0	0	0

† Pupae were filled with minute earthworms of undeterminable species.

TABLE 6. RESULTS OF EXAMINATION OF CORN

Environment	Locality	Cage No.	Date examined	Number of pupae recovered			Dead larvae recovered
				Alive	Dead	Total	
	CONNECTICUT		FALL				
Outdoors in cultivated loam soil	Mt. Carmel	1	Nov. 4	82	6	88	10
	Mt. Carmel	2	Nov. 11	74	13	87	10
	Milford	9	Nov. 5	59	29	88	19
	Milford	10	Nov. 15	64	9	73	25
Protected from rainfall, in soil of tobacco shed	Windsor	7	Nov. 6	31	17	48	51
			SPRING				
Outdoors in cultivated soil	Mt. Carmel	3	May 19	0	90	90	0
	Mt. Carmel	4	Apr. 21	0	79	79	6
	Milford	11	Apr. 26	0	89	89	1
	Milford	12	May 31	0	95	95	0
	New Haven	17	May 3	0	97	97	0
	New Haven	18	May 30	0	95	95	0
	MASSACHUSETTS						
In cultivated sand	West Dennis	19	Apr. 27	2	86	88	1
	West Dennis	20	Apr. 28	4	84	88	1
	CONNECTICUT						
Protected from rainfall, on floor of insectary	New Haven	5	May 2	0	87	87	4
	New Haven	6	May 29	0	93	93	4
Protected from rainfall, in soil of open shed	Mt. Carmel	15	May 17	0	96	96	0
	Mt. Carmel	16	May 18	0	98	98	0
Protected from rainfall, in soil of tobacco shed	Windsor	8	Apr. 20	0	63	63	34
	Windsor	13	June 1	0	75	75	25
	Windsor	14	June 1	0	73	73	30

EAR WORM HIBERNATION CAGES OF 1937-38

Total recovery	Depth of pupae in soil (inches)			Condition of the burrows			No. of earth-worms	Pupae encumbered by	
	Deepest	Shallow-est	Average	Open	Partly open	Closed		Roots	Earthworms
98	5.4	1.2	3.2	83	5	0	3	0	5
97	5.8	1.4	3.1	60	22	5	12	0	27
107	5.4	.8	3.0	75	13	0	8	0	29
98	4.4	1.2	2.9	72	1	0	0	0	.....
99	5.6	1.0	3.6	48	0	0	0	0	0
90	5.4	1.4	2.9	21	46	23	5	9	.....
85	5.4	.8	3.0	31	38	10	17	10	25
90	5.6	1.0	3.3	6	36	47	1	0	1
95	6.4	1.5	3.1	6	42	47	5	0	.....
97	7.8	1.5	3.6	28	51	18	0	0	0
95	7.1	.9	3.9	28	41	26	0	0	0
89	6.0	1.4	3.8	20	33	35	0	12	0
89	6.2	1.8	4.0	39	32	17	0	2	0
91	5.6	1.2	2.9	87	0	0	1	0	0
97	5.2	1.1	2.8	93	0	0	0	0	0
96	5.7	1.3	3.5	96	0	0	11	0	8
98	5.7	1.2	3.4	98	0	0	9	0	4
97	7.0	1.1	3.6	63	0	0	0	0	0
100	7.4	1.3	3.9	75	0	0	0	0	0
103	6.8	1.6	3.8	73	0	0	0	0	0

Survival of Pupae in Outdoor Cages

Survival in fall

Over the three-year period, four cages were examined during November at Mount Carmel and a like number at Milford. Of an expected population of 400 in the soil of the Mount Carmel cages, 387 were recovered, or 96.8 percent. Of these, 326, or 84.2 percent, were live pupae; 31, or 8 percent, were dead pupae; and 30, or 7.8 percent, were dead larvae. Of an expected population of 400 in the soil of the Milford cages, 391, or 97.8 percent, were recovered. Of these, 287, or 73.4 percent, were live pupae; 51, or 13 percent, were dead pupae; and 53, or 13.6 percent, were dead larvae. Thus it appeared that the Milford environment was less favorable for pupation and survival than the Mount Carmel environment, probably owing to the better soil drainage of the latter location. Whatever the environment, however, some larvae failed to pupate, and some pupae died during the fall.

Survival in spring

Over the three-year period 25 cages were examined during April and May. Live pupae were found in only five. In a cage at West Dennis, Mass., 41 live pupae were found on May 4, 1937 (cage 19, Table 5), a survival at the rate of 39.4 percent of recovered individuals. In two cages in this location examined on April 27 and 28, 1938, a total of six live pupae were recovered (cages 19 and 20, Table 6), or a survival at the rate of 3.3 percent of recovered individuals. Again, six live pupae were found in a cage of washed sand at Milford, examined on May 7, 1937, (cage 8, Table 5), or a survival at the rate of 12 percent of recovered individuals. Thus, during the three-year period, no living pupae were recovered in spring from outdoor cages in any soil environment other than sand.

In soil of an open shed at Mount Carmel, examined on May 1, 1937 (cage 15, Table 5), 36 pupae, or 38.3 percent, of recovered individuals were alive.

Survival in summer

Of 18 outdoor cages examined during summer, live pupae were recovered in but one, a cage at West Dennis, Mass., examined on July 23, 1937 (cage 20, Table 5). Only a single live pupa was recovered, but by this time moths had emerged from most hibernating pupae which had survived the winter. Three live pupae were recovered from a cage placed in the soil of an open shed at Mount Carmel when examined on July 28, 1937 (cage 16, Table 5).

Depth of Pupae in the Soil

The depth to which larvae dug before forming the emergence burrows, and at which they transformed to pupae, varied in the several localities and years. A few pupae were found only a little below the surface of the soil and some occurred at depths greater than 6 inches, but most (60.64 percent) of them were between 2 and 4 inches below the surface. The greatest, least, and average depths of pupae in each cage examined are given in Tables 4, 5, and 6, the numbers of pupae found at various depths during each year

are given in Table 7, and the average depths of pupae in the several environments and localities during the three years are given in Table 8. Larvae had dug deepest, on an average, in September, 1936, which was followed by the mildest winter and the highest survival, while they dug the shallowest burrows in September 1935, which was followed by the most severe winter of the period and the lowest survival.

Sand was the only soil in which pupae survived the winter outdoors during the three-year period. It is notable that the larvae dug deeper in sand (soil of West Dennis, Mass., and washed sand at Mount Carmel and Milford, Conn.) than in other soils each year. The deeper location of pupae in the sand, with correspondingly greater protection against the lowest winter temperatures, together with the much better drainage, may have been important factors in the survival of pupae.

TABLE 7. DEPTH OF CORN EAR WORM PUPAE BELOW THE SURFACE OF THE SOIL

Depth of pupae (inches)	Pupae recovered at different depths				
	1935-36	1936-37	1937-38	Total	%
Less than 1	17	6	5	28	0.63
1.1 to 2	238	187	146	571	12.90
2.1 to 3	357	421	530	1,308	29.54
3.1 to 4	313	460	604	1,377	31.09
4.1 to 5	234	288	299	821	18.54
5.1 to 6	70	107	84	261	5.90
6.1 to 7	9	22	19	50	1.13
7.1 to 8	....	8	3	11	.25
8.1 to 9	....	1	....	1	.02
Total	1,238	1,500	1,690	4,428	

Durability of the Emergence Burrows

In order that moths may emerge during spring or summer it is necessary that the emergence burrows prepared by the larvae remain open. Emergence burrows in cages that were protected from precipitation and that contained no earthworms or other fauna, or growing plants, remained open perfectly. Such was the condition of burrows in cages placed in an open shed at Mount Carmel, in a tobacco shed at Windsor, and in an insectary at New Haven. But in outdoor environments the number of partly or wholly closed burrows increased progressively from the time when dug by the larvae until the following summer. Table 9 summarizes the records for the three years of burrow conditions found on examination of cages located outdoors. Although, on examination during fall, 88.06 percent of burrows were open, only 24.76 percent were found in this condition in spring, and by summer only an average of 7.54 percent were open.

Burrows remain open in some soils more perfectly than in others. Thus, at Mount Carmel, in well-drained loam containing some gravel, burrows remained open longer than at Milford, where the loam was less well drained and contained no gravel. In sand at West Dennis they remained open until

TABLE 8. AVERAGE DEPTHS BELOW THE SOIL SURFACE AT WHICH CORN EAR WORM PUPAE WERE RECOVERED IN DIFFERENT ENVIRONMENTS

Environment	Locality	Average depth of pupae (inches)			
		1935-36	1936-37	1937-38	All seasons
Outdoors:					
In cultivated soil	Mt. Carmel	2.59	3.76	3.05	3.17
	Milford	3.51	2.98	3.11	3.21
	New Haven	2.34	3.21	3.76	3.18
	West Dennis[1]	3.69	3.68	3.93	3.76
Average for the above four soils		3.12	3.39	3.35	.....
In washed sand	Mt. Carmel	3.68	3.73	.....	3.71
	Milford	4.00	4.70	.....	4.35
In alfalfa field	Mt. Carmel	2.46	.....	.....	.....
Protected from rainfall:					
In soil of an open shed	Mt. Carmel	.....	2.82	3.47	3.16
In soil of a tobacco shed	Windsor	.....	.....	3.73	.....

[1] Town in Massachusetts; others are in Connecticut.

TABLE 9. CONDITION OF THE EMERGENCE BURROWS OF THE CORN EAR WORM AT DIFFERENT PERIODS OF THE YEAR

Period of the year	Number of cages examined	Burrows Found in the Specified Conditions						Total number of pupae recovered
		OPEN		PARTLY OPEN		CLOSED		
		Number	Percent	Number	Percent	Number	Percent	
Fall	8	612	88.06	65	9.35	18	2.59	695
Spring	15	339	24.76	608	44.41	422	30.83	1,369
Summer	18	96	7.54	648	50.90	529	41.56	1,273

TABLE 10. CONDITION OF EMERGENCE BURROWS OF THE CORN EAR WORM IN THREE SOILS AT DIFFERENT PERIODS DURING THREE YEARS

Season and soil type	Locality	Number of cages	Burrows Found in the Specified Conditions						Total number of pupae recovered
			Open		Partly open		Closed		
			Number	Percent	Number	Percent	Number	Percent	
FALL:									
Gravelly loam	Mt. Carmel	4	324	90.76	28	7.84	5	1.40	357
Loam without gravel	Milford	4	288	85.21	37	10.95	13	3.84	338
SPRING:									
Gravelly loam	Mt. Carmel	4	79	22.83	170	49.13	97	28.04	346
Loam without gravel	Milford	4	21	5.88	148	41.46	188	52.66	357
Sand	West Dennis[1]	4	144	37.80	159	41.73	78	20.47	381
SUMMER:									
Gravelly loam	Mt. Carmel	3	28	14.58	102	53.13	62	32.29	192
Loam without gravel	Milford	4	5	1.67	171	57.00	124	41.33	300
Sand	West Dennis[1]	2	3	1.78	94	55.62	72	42.60	169

[1] Town in Massachusetts.

spring, more perfectly than in loam either at Mount Carmel or Milford, but were destroyed more rapidly during the period between spring and summer examinations. A comparison of the condition of emergence burrows in these three soil types during three seasons over a three-year period is given in Table 10.

Factors Leading to Destruction of Burrows

Many factors influence the durability of the emergence burrows, but none seems to be more important generally than alternate freezing and thawing of the soil, the activities of earthworms, and the penetration into them of roots of growing plants.

Heaving of the Soil

The soil of southern New England usually has a high moisture content due to abundant and frequent rainfall. When it freezes expansion occurs, which results in some parts being thrust upward. On thawing the soil contracts, and if it has been frozen deeply the contraction results in the opening of fissures several inches deep similar to those occurring in the drying of clay.

In our experiments this was more noticeable in soils of high clay content, such as occur in the Milford environment, less noticeable in soil with some sand content, such as that at Mount Carmel and at New Haven, and least noticeable in soil of high sand content, such as that of West Dennis, Mass. No such effect was observed in soil protected against winter precipitation, such as that under the shed at Mount Carmel, in the insectary at New Haven, or in the tobacco shed at Windsor. The emergence burrows remained in perfect condition after repeated and heavy rainfall, but the movement of soil during freezing and thawing, or in drying after saturation, caused cracks to open which interrupted the walls of the burrows. Observations seemed to show that soil may then be washed into them and the pupae buried. The degree to which the burrows are filled in this way and the number affected depend not only on the soil type and its susceptibility to cracking but on the depth to which the soil has been frozen and the number of times it was frozen and thawed during winter.

Earthworms

Earthworm populations vary from many to none, depending on the type of soil and its moisture and humus content. Such differences were observed in the soils in which hibernation cages were set, and the average recovery of earthworms per cage is given in Table 11. The most abundant earthworm population was found in Milford loam, the least in sandy soils. Undisturbed soil protected from rainfall contained none, probably because it was too dry.

The earthworms observed in these cages varied from minute, recently hatched individuals feeding in dead pupae to full-grown specimens. Depending on the moisture content of the soil, they were found at depths from near the surface to below the bottoms of cages. They were usually active during fall and spring but were frequently found resting in cells at various depths during dry periods of summer.

In their burrowing and feeding activities earthworms often penetrate into and disrupt the walls of ear worm emergence burrows. Often they use these burrows, depositing their excrement therein, partly filling them, or covering the pupae with this material. Thus, in a cage at Mount Carmel examined on November 11, 1937 (cage 2, Table 6), earthworm excrement had been deposited on 22 of 74 live pupae, or 29.7 percent, and on 5 of 13 dead larvae, or 38.5 percent. Examination of a cage in the same locality on April 21, 1938 (cage 4, Table 6), showed that earthworm excrement had been deposited on 25 of 79 dead pupae, or 31.6 percent, and on 4 of 6 dead larvae, or 66.7 percent. When pupae die and decompose, earthworms often feed on them and so mix the deteriorating pupal exoskeleton with excrement that eventually all trace of the pupa is lost. In a cage examined on May 17, 1938 (cage 15, Table 6), 8 of 11 earthworms recovered, or 72.7 percent, were feeding on dead pupae in emergence burrows. As a further example, in a cage at Milford examined on April 30, 1937 (cage 11, Table 5), of 97 pupae recovered, 37, or 38.1 percent, were buried in earthworm excrement, and 15, or 15.5 percent, were probably being fed upon by earthworms which were found in conjunction with them.

Roots of growing plants

In the area of these studies, plants do not grow materially after ear worms enter the soil in September until the following April, but subsequently their growth is rapid. Roots are thrust into the ear worm emergence burrows, and, when sufficiently abundant, these burrows may be filled so completely as to prevent emergence of the moths. Where the pupae have died and are decomposed, the roots penetrate such pupae and their surroundings in especially large numbers and apparently obtain food from them.

In a cage at Mount Carmel, examined on July 27, 1937 (cage 5, Table 5), on which a stand of grass had appeared, 69 of 78 dead pupae recovered, or 88.5 percent, were encompassed by roots. Again, in a cage at West Dennis, Mass., examined on July 23, 1937 (cage 20, Table 5), 48 of 76 pupal remains recovered, or 63.2 percent, were encompassed by roots of grass. In this latter cage, one of 5 moths recovered had been prevented from reaching the surface of the soil by roots which partly filled the emergence burrow, and this individual had died in the soil in consequence.

Emergence of Moths

Moths emerged from three outdoor cages during the summer of 1937. One individual emerged from a cage in washed sand at Milford (cage 8, Table 5). Five moths and one live pupa were recovered from a cage at West Dennis, Mass., on July 23, 1937 (cage 20, Table 5), and four moths and three live pupae were recovered from a cage placed in soil under an open shed at Mount Carmel, examined on July 28, 1937 (cage 16,Table 5). None emerged from other soils outdoors.

RESULTS OF EXAMINATION OF CAGES PLACED IN PROTECTED LOCATIONS

It was shown in the section on seasonal abundance that the infestation that occurred during the three summers, 1935, 1936, and 1937, arose from relatively few moths that were in flight during June and July. In order to

TABLE 11. OCCURRENCE OF EARTHWORMS IN THE SOIL OF CORN EAR WORM HIBERNATION CAGES DURING THREE YEARS

Environment	Locality	Average number of earthworms recovered		
		Fall	Spring	Summer
Outdoors:				
In cultivated soil	Mt. Carmel	3.8	10.2	1.0
	Milford	13.5	19.5	24.2
	New Haven	.....	0.3	0.3
In cultivated sand	West Dennis[1]	.....	2.0	0.0
In washed sand	Mt. Carmel	.....	0.0*	.....
	Milford		0.0	.....
Cages under corn shocks	Mt. Carmel	.....	.....	1.5
	Milford	.....	.....	30.5
Cages in alfalfa field	Mt. Carmel	.....	.....	25.5
Protected from rainfall:				
In soil of an open shed	Mt. Carmel	.....	6.7**	0.0
In soil of a tobacco shed	Windsor	0.0	0.0	.....

[1] Town in Massachusetts, all others in Connecticut.

* Minute earthworms were found filling 8 of 52 dead pupae in one cage (cage 6, table 5).

** In 1936-37, in soil that had been undisturbed for several years, none was recovered. In 1937-38, in fresh soil placed in the cages during the summer of 1937, an average of 10 per cage was recovered in the spring examination.

account for their presence, it is not necessary to suppose that all or any of these moths emerged from pupae that overwintered outdoors. Such small numbers could readily have come from pupae which passed the winter in locations protected from precipitation and from the lowest temperatures.

During the fall cornstalks are often cut and stored in sheds or barns for use during the winter. Ears are sometimes harvested in the shuck and stored in bins or barns to be shucked later on, or roasting ears may be picked and allowed to lie for various periods in trucks or wagons under sheds or in barns before they are marketed. Above all, roasting ears lie in roadside markets for days at a time. In all such instances it is likely that some ear worms which mature in corn handled as indicated, and leave the ears, find quarters in which to pupate and in which they are protected during winter.

From such pupae moths may emerge the following summer and escape outdoors. In fact, emergence of a moth in one such instance has been recorded. At the New Haven laboratory there is an unheated room with a sand floor located under a porch. This room is surrounded by tight walls, one of which has outside windows. Stalks of sweet corn were collected during the fall of 1936 and stored in this room for use during the winter. On August 17 a fresh, newly emerged ear worm moth appeared. There was no apparent way in which this moth could have gained access to the room except by emerging from the sand of the floor. It seems reasonable to believe that the larva was feeding in a late nubbin ear when the cornstalks were brought into the room during the fall, that it matured, entered the earthen floor to pupate, and that, protected from the lowest temperatures and from precipitation, the pupa survived and the moth emerged.

To determine the rate of survival of pupae in the protected locations indicated, portable wooden cages containing about a cubic foot of earth were prepared. During the winter of 1936-37 these cages contained Mount Carmel loam and during the winter of 1937-38 they contained sand. Into the soil of each cage 25 larvae were allowed to dig overwintering burrows in the same way as with the larger cages described. These cages received no moisture at any time. Their locations are given in Table 12, where the results obtained are summarized. During each winter a relatively high percentage of pupae survived in these cages, but during the mild winter of 1936-37 the survival was at a greater average rate than during the colder winter of 1937-38.

Emergence of moths from pupae hibernating under dry conditions usually occurs later than from pupae provided with moisture. From pupae stored under dry, cool conditions during the winter of 1936-37, and the following spring and summer, moths emerged from July 7 to September 5. The moths that emerged during July, August, and September were 49.12, 47.37, and 3.51 percent, respectively, of the total number. This information is summarized in Table 13. During this period the temperature of the room in which the cages were placed varied from 69° to 78° F., but it was usually about 74° F.

It is of interest to note that the earliest ear worm infestations were found during 1935 and 1936 in July, the first eggs being laid on corn probably not earlier than the first week of this month. According to the information given in Table 13, this is the period when moths begin to emerge from dry hibernation in protected places.

TABLE 12. SURVIVAL OF CORN EAR WORM PUPAE IN CAGES CONTAINING A CUBIC FOOT OF EARTH PLACED IN PROTECTED LOCATIONS

Environment	Locality[1]	Emerged during fall	Date examined	Total recovery	No. of dead larvae	No. of dead pupae	No. of live pupae	Percentage of survival
WINTER OF 1936-37:								
Hay loft of barn	Mt. Carmel	0	May 10	21	0	6	15	71.4
Horse barn	Mt. Carmel	0	May 10	25	0	12	13	52.0
Insectary	New Haven	2	May 10	22	0	13	7	35.0
Room at 40° F.	New Haven	0	May 10	24	1	7	16	69.6
Cool basement room	New Haven	0	Aug. 28	24	0	8	16*	66.7
WINTER OF 1937-38:								
Hay loft of barn	Mt. Carmel	1	May 24	25	0	19	5	20.8
Horse barn	Mt. Carmel	6	May 24	24	2	6	10	62.5
Open shed	Mt. Carmel	4	May 24	25	1	20	0	0.0
Insectary	New Haven	5	May 24	23	1	12	5	29.4
Cool basement room	New Haven	6	May 24	25	0	13	6	31.6

[1] All towns in Connecticut.
* Moths were allowed to emerge from the undisturbed cage. By the date mentioned 15 had emerged and one live pupa remained.

DISCUSSION

The results of the investigation described seem to show that the corn ear worm survives the winter in southern Connecticut. Although the survivors are probably a very small percentage of those that enter hibernation, it seems not unreasonable to believe that they are sufficient in number to account for the small rate of infestation that has occurred during June or July of recent years. Under cage conditions, pupae survived the winter only in sandy soils or in locations protected from winter precipitation and temperatures. They probably occasionally survive in soil of lower sand content if it is well drained.

It seems reasonable to conclude that it is not necessary to look further for an explanation of the annual occurrence of the insect in this area. Infestations of the three summers from 1935 to 1937 appear to have resulted as a natural increase in population from the small number of individuals that emerged during June or July each year.

TABLE 13. PERIOD OF EMERGENCE OF CORN EAR WORM MOTHS FROM HIBERNATION IN A COOL, DRY ENVIRONMENT, NEW HAVEN, CONN., 1937

Time	Moths emerging	
	No.	Percentage of total
By periods:		
July 6-10	6	10.53
11-15	8	14.03
16-20	4	7.02
21-25	3	5.26
26-31	7	12.28
Aug. 1-5	13	22.81
6-10	7	12.28
11-15	1	1.75
16-20	4	7.02
21-25	0	0
26-31	2	3.51
Sept. 1-6	2	3.51
By months:		
July	28	49.12
August	27	47.37
September	2	3.51
Total for season	57	

SUMMARY

The annual occurrence of the corn ear worm (*Heliothis obsoleta F.*) in southern Connecticut during recent years raised a question as to the source of this infestation. Experiments to determine whether the insect passed the winter successfully were begun in the fall of 1935 and continued until the spring of 1938.

The seasonal abundance of the insect during the three summers 1935, 1936, and 1937 showed that annual populations began with a few individu-

als which occurred in the earliest sweet corn during June or July. Populations which occurred during August and September could be traced to natural increases from these first-occurring individuals, when considered in connection with the corn acreage attractive to the ovipositing moths during the season.

Most pupae were found at depths of from 2 to 4 inches below the surface of the soil, but they occurred deeper in sandy than in other soils.

Progressive destruction of the emergence burrows, which are dug by the larvae to enable the moths to escape from the soil, occurred in outdoor cages from the time the insects entered hibernation during September until the following summer. Destruction of these burrows was due to several factors, of which freezing and thawing of the soil, the activity of earthworms, and growth of roots of plants were the most important.

Pupae survived the winter in sandy soil at West Dennis, Mass., during two years, and in washed sand at Milford, Conn., during one year. They also survived in cages located in the soil of an open shed at Mount Carmel, Conn., one year. In locations protected from precipitation and extreme ranges in temperature they survived in large numbers. Moths emerged during summer from these locations.

It was concluded that the insect survived the winter in certain environments in southern New England, at least during some years. The number of survivors seemed adequate to account for the annual infestations that have occurred.